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Question:
During the period of the fishery, has the carrying capacity of the ETP for dolphins declined substantially or has the ecological structure of the ETP changed substantially in any way that could have impeded depleted dolphin stocks from growing at rates expected in a static ecosystem? Or has the carrying capacity increased substantially or has the ecological structure changed substantially in any way that could promote depleted dolphin stocks to grow at rates faster than expected in a static ecosystem?

Answer:
There are indications that the biological productivity of the ETP has changed in response to the low-frequency physical variability known as the Pacific Decadal Oscillation (PDO). These indications, while speculative, require that we not rule out the possibility that the carrying capacity of the ETP for dolphins has declined and that this decline has affected recovery of the population. Recent observations of the PDO and model studies of the Pacific basin ocean ecosystem provide a basis to hypothesize how the carrying capacity may have been reduced.

There is little evidence that the ecological structure of food webs in the ETP has changed substantially, but quantitative changes in oceanic ecosystems are usually coupled to qualitative changes in the food web (Barber and Chavez, 1983 and 1986). Therefore, we also cannot rule out the possibility that the ecological structure of the ETP has changed substantially in a way that could impede the recovery of the dolphin stocks.

Rationale:
Recognition of pervasive, coherent, low-frequency physical variability and its influence on biological processes in the North Pacific Ocean is one of the major advances in biological oceanography in the last 10 years. The biological consequences of PDO variability at temperate latitudes of the North Pacific are well documented (for example, Hare and Mantua, 2000). While there are few observations in the ETP that show a strong PDO influence, modeling studies suggest that there is a strong influence but that this influence has a subsurface rather than a surface manifestation. Fei Chai (U. Maine), Richard Dugdale and Frances Wilkerson (San Francisco State U.), T.-H. Peng (NOAA AOML) and I have developed a 10-component physical-biological ecosystem model to investigate the biological and biogeochemical consequences of climate variability in the Pacific basin. A 1960 – 2000 retrospective analysis of the tropical Pacific enables us to examine the physical changes and their biological consequences in the ETP region of concern in this NMFS assessment.

Model results from our retrospective analysis indicate that when the PDO is in a strong positive phase, as it has been since the mid-1970s, heat storage in the surface mixed layer is increased, forcing the thermocline and nutricline deeper. A deeper nutricline reduces primary productivity in this permanently stratified habitat because deepening the nutricline further separates the nutrient source from the light supply.

Comparison of a section in the core ETP region for July 1971 (Fig. 1) with the same section for July 1998 (Fig. 2) shows the deepening of the nutricline in the more recent period. A time series of nitrate concentrations at 40 m from the core of the ETP (10°N, 110°W) shows a clear change in the nitrate distribution following the mid-1970s (Fig. 3). This model result suggests that concentrations below the rate limiting concentration for nitrate uptake, 0.1 – 0.5 µmol/l (MacIsaac and Dugdale, 1969), prevailed for some period each year in the decades following the mid-1970s. Before the mid-1970s, the nitrate concentration at 40 m varied considerably, but the minimum concentration rarely reached rate limiting levels. The PDO variability affected minimum annual nitrate concentrations more than mean concentrations. This is a form of environmental change that is extremely difficult to detect with sparse shipboard sampling. In essence, continuous observation would be required to resolve such changes.

If nutrient availability is reduced in oceanic food webs, large primary producers and zooplankton become less abundant, leaving small producers and zooplankton to dominate. Even if there is no significant change in overall primary productivity, such a change in food web structure increases the efficiency of recycling at the lower trophic levels and reduces the amount of food that is passed up the food web to higher trophic level organisms such as dolphins.

In the equatorial region, modeled productivity, silicate and nitrate anomalies covary with the observed PDO Index such that a positive PDO Index is associated with anomalously low productivity, silicate and nitrate (Fig. 4). Model estimates of nutricline variability in the ETP region (Fig. 1 – 3) support the suggestion that a similar relationship exists in the ETP. Because the PDO is strongly tied to the physical dynamics of the North Pacific basin, nutricline variability in the ETP around 10°N may experience vertical displacements that are even stronger than those in the equatorial region.

Two dolphin species that the NMFS Panel is concerned with, northeastern offshore spotted dolphins and eastern spinner dolphins, appear to have a unique habitat preference (or perhaps requirement) for a surface layer of warm, clear water and, beneath this layer, a shallow nutricline that supports moderately high primary productivity and a rich pelagic food web. Such a dual requirement would make these dolphins particularly vulnerable to physical processes such as the PDO that modify nutricline topography.

In conclusion, while the available primary productivity observations show that the ETP remains a relatively rich habitat, it is reasonable to accept the model suggestion that it is less rich during positive phases of the PDO Index, such as the phase that began in the late 1970s, and that this decrease in productivity would reduce the carrying capacity of the ETP for dolphins.

References:

Barber, R. T. and F. P. Chavez (1983) Biological consequences of El Niño. *Science* 222: 1203-1210.

Barber, R. T. and F. P. Chavez (1986) Ocean variability in relation to living resources during the 1982-83 El Niño. *Nature* 319: 279-285.

Chai, F., R. C. Dugdale, T.-H. Peng, F.P. Wilkerson and R.T. Barber (2002) One dimensional ecosystem model of the equatorial Pacific upwelling system. Part I: model development and silicon and nitrogen cycle. *Deep-Sea Res. II* 49: 2713-2745.

Dugdale, R. C., A. G. Wischmeyer, F.P. Wilkerson, R.T. Barber, F. Chai, M.-S. Jiang and T.-H. Peng (2002a) Meridional asymmetry of source nutrients to the equatorial Pacific upwelling ecosystem and its potential impact on ocean-atmosphere CO2 flux: a data and modeling approach. *Deep-Sea Res. II* 49: 2513-2531.

Dugdale, R. C., R. T. Barber, F. Chai, T.-H. Peng, and F. P. Wilkerson (2002b) One-dimensional ecosystem model of the equatorial Pacific upwelling system. Part II: sensitivity analysis and comparison with JGOFS EqPac data. *Deep-Sea Res. II* 49: 2747-2768.

Hare, S. R. and N. J. Mantua (2000) *Progress in Oceanography* 47: 103.

MacIsaac, J. J. and R. C. Dugdale (1969) The kinetics of nitrate and ammonia uptake by natural populations of marine phytoplankton. *Deep-Sea Res.* 16: 47-58.

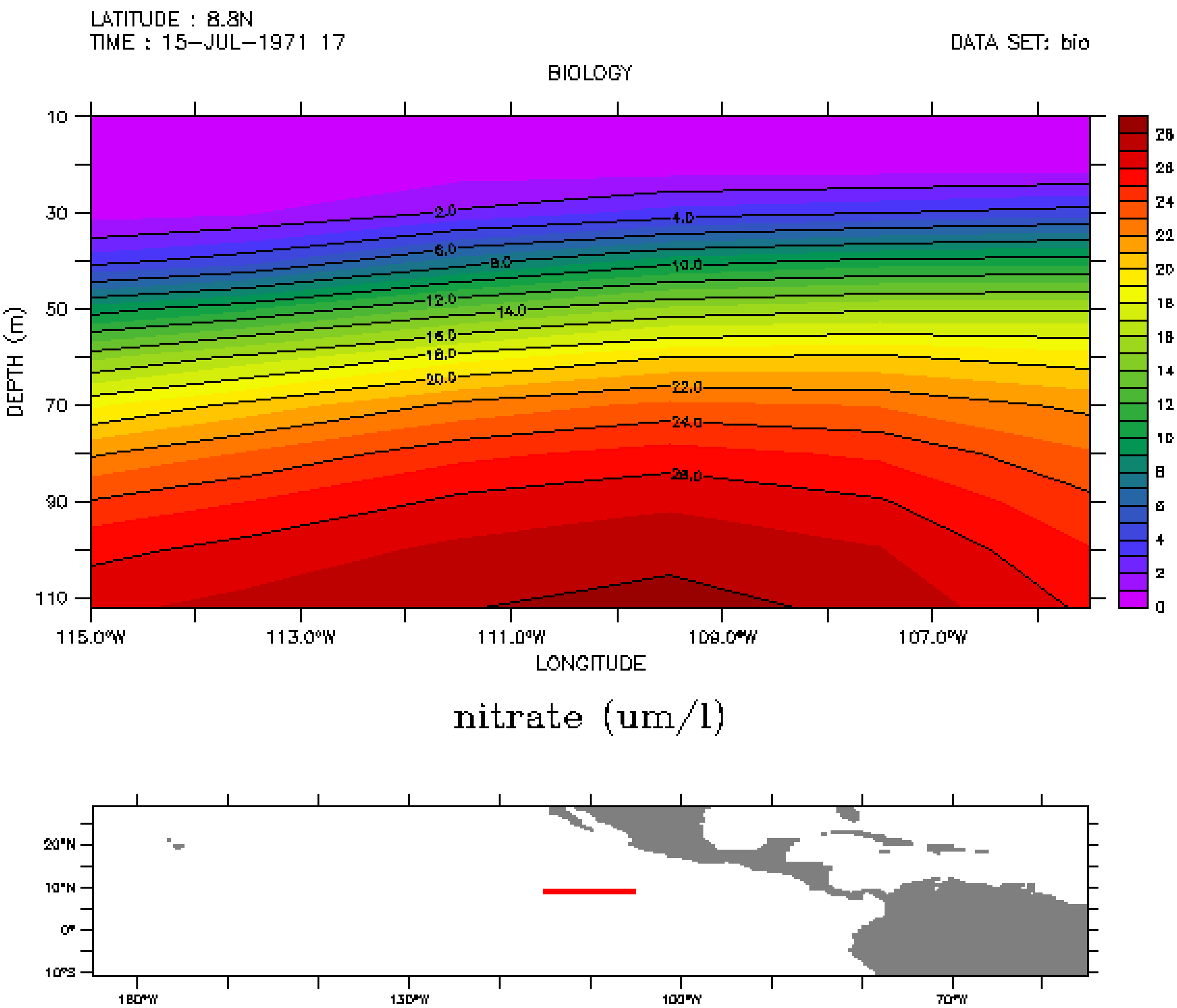

Figure 1. A longitude vs depth section of nitrate in the core region of the eastern tropical Pacific (ETP) for July 1971. Units are μmol/l of nitrate. The lower panel shows the position of the section._ These results are from a Pacific basin ecosystem model described in Chai et al. (2002), Dugdale et al. (2002a) and Dugdale et al. (2002b).

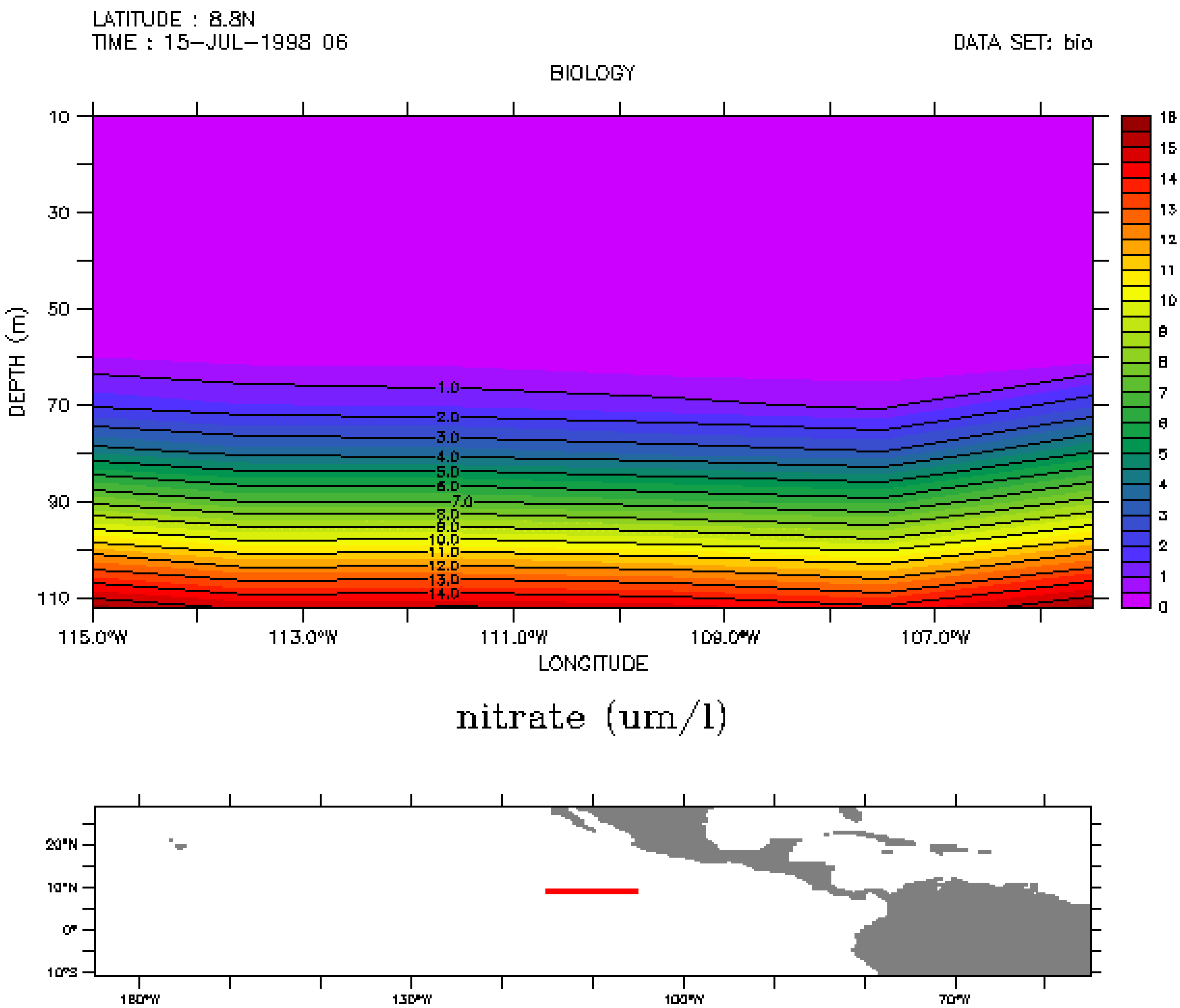

Figure 2. A longitude vs depth section of nitrate in the core region of the eastern tropical Pacific (ETP) for July 1998. Units are µmol/l of nitrate. The lower panel shows the position of the section._ These results are from a Pacific basin ecosystem model described in Chai et al. (2002), Dugdale et al. (2002a) and Dugdale et al. (2002b).

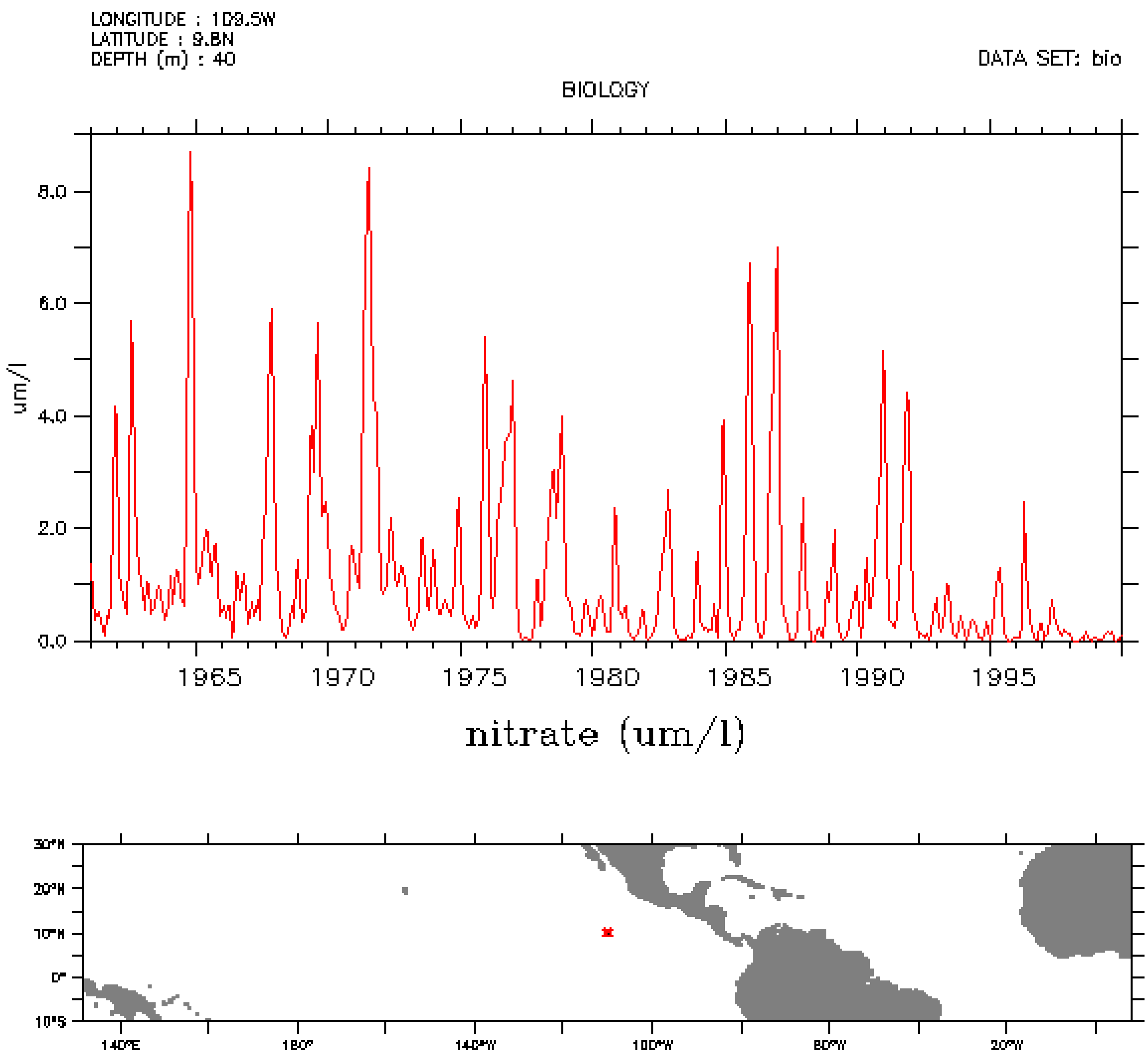

Figure 3. A time series of nitrate concentration in μmol/l at 40 m in the core of the ETP region (10°N, 110°W). These results are from a Pacific basin ecosystem model described in Chai et al. (2002), Dugdale et al. (2002a) and Dugdale et al. (2002b).

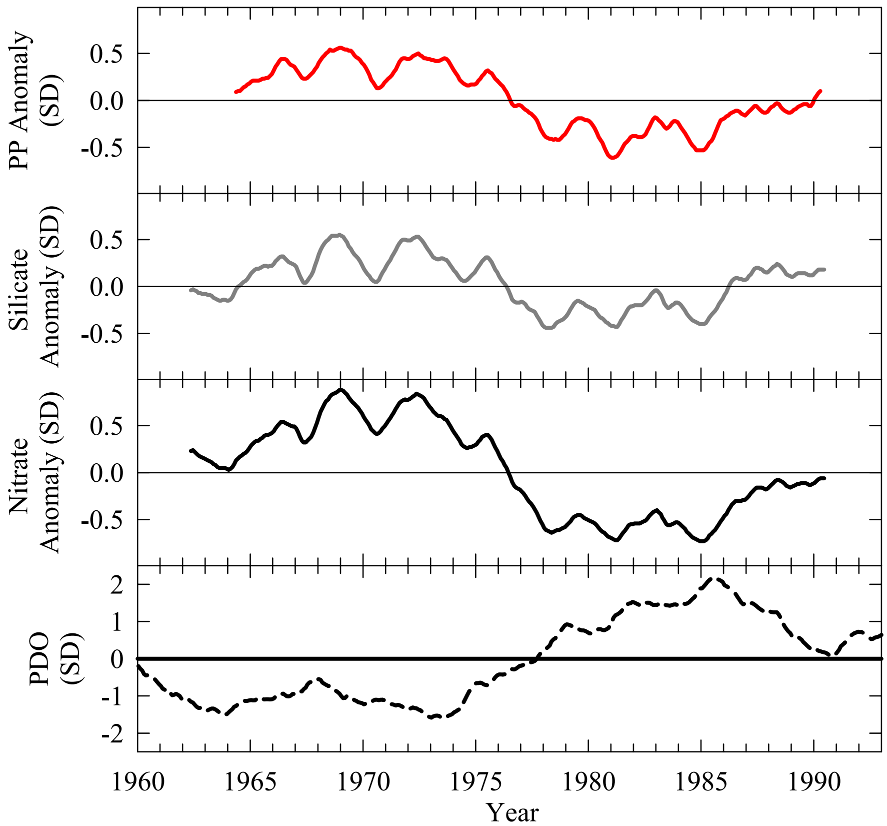

Figure 4. Decadal variability of primary productivity, silicate and nitrate anomalies for the eastern equatorial Pacific Ocean and the Pacific Decadal Oscillation (PDO) Index. Primary productivity, silicate and nitrate values are output from a 10-component physical-biological model described in Chai et al. (2002), Dugdale et al. (2002a) and Dugdale et al. (2002b); the PDO Index is based on observed sea surface temperature anomalies in the North Pacific Ocean north of 20°N.